

**RECYCLING OF LIGNOCELLULOSE BASED BOARD MATERIALS**

The present invention relates to the recycling of lignocellulose based board (or panel) material comprised of a matrix of adhesively bonded lignocellulosic elements so as to permit recovery of constituents of the board material, particularly but not exclusively of the lignocellulose.

It is well-known that various board materials comprise a matrix of lignocellulosic elements (e.g. in the form of chips, particles or fibres) bonded together by means of an adhesive such as, for example, a polyurethane, urea/formaldehyde, melamine-urea or phenolic resin. Examples of board materials produced in this way include MDF (Medium Density Fibreboard), particle board and chip board.

Board materials of the type described above are used extensively for producing finished articles such as, for example, furniture. For this purpose, the board materials are entirely satisfactory. However there is a substantial amount of waste material for which disposal poses a problem. To illustrate the point, the UK furniture manufacturing industry generates over 170,000 tonnes of MDF waste every year. This does not include rejected and damaged furniture items. Ideally the waste material would be recycled to recover constituents thereof, particularly the lignocellulose for reuse. However, no satisfactory recycling process is currently available. The problem is made worse by the fact that the waste board material may be laminated to a surface layer such as, for example, paper foil or plastics (e.g. for decorative purposes) or may have, for example, plastic or metal inserts. As such, any

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recycling process will need to remove the laminates and/or inserts. In the absence of any suitable recycling process, most of the waste board material will be dumped in landfill site, which is becoming more difficult and very expensive.

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It is an object of the present invention to obviate or mitigate the above mentioned disadvantages.

According to the present invention there is provided a  
10 method of recovering a constituent of a board material  
comprised of a matrix of adhesively bonded lignocellulosic  
elements, the method comprising subjecting the material to a  
combination of (i) electromagnetic radiation and (ii)  
soaking or immersion in a liquid medium, and recovering the  
15 constituent.

The constituent to be recovered will generally comprise  
lignocellulose, which may, however, incorporate residual  
resin, for example urea-formaldehyde resin.

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The electromagnetic radiation will typically have a  
frequency in the range of from 100 kHz to 300 GHz, more  
typically from 10 MHz to 300 GHz.

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The liquid medium will typically comprises water or an  
aqueous solution. The liquid medium could, however,  
comprise any suitable organic or inorganic solvent capable  
of swelling the material so that the constituent can be  
recovered. Possible other examples include ethyl alcohol,  
30 ethyl alcohol/water mixtures, and dilute sodium hydroxide  
(for example 0.1-9% by volume). This latter example has  
been found to improve fibre texture.

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The invention has been based in part on our discovery that treatment of board materials comprised of an adhesively bonded matrix of lignocellulosic elements, for example  
5 particles or fibres, by exposure to electromagnetic energy in the frequency range of from 10 MHz to 2500 MHz and soaking with a liquid medium such as water produces substantial swelling of the board material, which, we believe, mechanically disrupts and possibly at least -  
10 partially hydrolyses the adhesive bonding the lignocellulosic elements together so that these elements can now be readily separated from each other. The degree of swelling achieved is considerably more than that which is obtained simply by soaking the board material in the liquid  
15 medium.

Steps (i) and (ii) may be effected simultaneously or sequentially. The degree of swelling achieved in the thickness dimension of the board should generally be in the  
20 range of from 3 to 6 times the original thickness.

Separation of the lignocellulosic elements from each other may be achieved using a relatively low degree of mechanical agitation while the treated material is in the  
25 liquid medium, for example water. Once the elements have been separated, it is possible to recover a desired constituent of the board, which will usually comprise the lignocellulose. Thus, for example, the resultant dispersion of fibres may be dried, for example by press-drying (if the  
30 fibres are to be transported) or by a fan-assisted blowing system (if the fibres are to be re-used on site). Moreover, surface laminates, for example paper, foil, melamine, veneer

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or other finishes commonly used on board materials to which the invention relates, can readily be separated from the treated board prior to recovery of the fibres, for example by agitation, as may inserts or other bodies included in the panels.

The board material will typically have a density of from 200 Kg m<sup>-3</sup> to 1200 Kg m<sup>-3</sup>.

10 The invention is applicable to a wide variety of wood based boards, including particle boards and fibre boards. Specific examples of board materials to which the present invention is applicable include MDF, chip board, hard board, soft board, orientated strand board, flax board and wood  
15 chip board, and combination of any two or more thereof.

The invention is applicable both to industrial- and consumer- waste board material.

20 The electromagnetic radiation used in the process of the invention preferably has a frequency in the range of from 10 MHz to 300 GHz, more preferably from 10 MHz to 2500 MHz. These frequencies have been found to result in substantial swelling of the board material in the liquid  
25 medium. The power is preferably in the range of from 500 W to 30 kW, more preferably from 3 kW to 15 kW, although certain values in these ranges may be more applicable to some materials rather than others. Thus, for example, the power used should preferably not be so high as to cause  
30 charring of the board material. The optimum parameters may readily be determined by a person skilled in the art.

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It is particularly preferred that microwaves in the frequency range from  $896 \pm 20$  MHz to  $2450 \pm 25$  MHz are employed (such as generated by a magnetron). Thus, for example, the electromagnetic radiation used may be  $896 \pm 20$  MHz or  $2450 \pm 25$  MHz, both of which are frequencies reserved for domestic/industrial microwave use. These frequencies have been found to result in substantial swelling of the board material in the liquid medium.

10        Alternatively the electromagnetic energy may have a frequency in the range of from 10 MHz to 50 MHz.

For all embodiments the microwaves may be generated by means of a magnetron in a conventional way. The power output to the cavity, which may, for example, be in the form of a metallic vessel or pipe, is preferably in the range 500 W to 30 kW. The microwaves propagate through the cavity, which contains the wood-based panels immersed in the liquid medium such as water.

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Electromagnetic radiation having a frequency in the range of from 100 kHz to 100 MHz may also be used, which is typical of radio frequency (RF) waves. Thus, the process according to the present invention is not restricted to the use of microwaves. RF may also be utilised due to the lower frequencies of operation resulting in greater penetration through the board, which is often advantageous. RF may be defined as all frequencies used for communication, corresponding to 100 kHz to 300 GHz. Further details may be found in Kitchen, R. (2001) RF and Microwave Radiation Safety. Newnes pp1-2.

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The invention may be practised in a number of ways. In a particularly preferred embodiment, the board material is initially subjected to the electromagnetic radiation and is then immersed substantially immediately into the liquid medium, for example within 5 to 15 seconds. The liquid medium, for example water, is preferably at an elevated temperature, for example 60°-90°C, preferably about 80°C. For this embodiment, it is desirable that the board material does have internal moisture content, preferably a minimum of 8%, which may, if necessary, be enhanced prior to the treatment with electromagnetic radiation. Immersion of the board material that has been subjected to electromagnetic radiation into the liquid medium causes substantial swelling to occur. Typically the exposure time to the electromagnetic radiation will be in the range of from 30 to 90 seconds. Subsequently the material is soaked in the liquid medium to swell the material. Typically the degree of swelling may be to 3 to 6 times the original degree of thickness, for which an immersion time of typically 10-25 minutes in, for example, water may be required, although the exact time will depend on factors such as the nature of the board, the parameters employed (for example frequency and power) employed during the treatment with electromagnetic energy, and the temperature of the water.

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Any surface laminate applied to the board may easily be removed from the swollen board (and in fact the laminate may start to peel-off during the treatment with electromagnetic radiation). Similarly any inserts may also be removed easily. The swollen material may then readily be converted to a fibrous suspension using, for example, a moderate

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degree of agitation such as provided a low power mechanical blender, for example.

The fibrous suspension may then be dried, for example  
5 by press-drying or by means of a fan-assisted blowing system  
as described previously.

This embodiment of the invention may be effected on a  
continuous or semi-continuous basis by, for example, passing  
10 the material to be treated through or passed a microwave  
source (with the material, for example, being on a conveyer  
belt) and then introducing the material into a tank of  
liquid medium (for example water) for the desired residence  
time therein.

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In an alternative, but less preferred, embodiment of  
the invention, the board materials is immersed in the liquid  
medium (for example water) and subjected to electromagnetic  
radiation as discussed previously followed by soaking in the  
20 liquid medium without irradiation. All other conditions  
being equal, this embodiment of the invention tends to  
produce a lower degree of swelling of the board than the  
above described preferred embodiment and does not lend  
itself as readily to continuous or semi-continuous operation  
25 as the above described preferred embodiment. It may however  
be possible to recover heat from the liquid medium using,  
for example, a heat exchanger to assist in drying of the  
board. Moreover, this embodiment involves not only heating  
of the board material by the electromagnetic radiation but  
30 also the liquid medium in which it is immersed, thus  
reducing energy efficiency. Furthermore, it is envisaged

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that this embodiment may provide more problems with effluent disposal than the above described more preferred embodiment.

For all embodiments of the invention, the board  
5 material may initially be subjected to a vacuum impregnation so as to increase its moisture content, for example up to 50% by weight. Alternatively, or additionally, the liquid medium in which the board is immersed may incorporate an additive such as, for example a surface active agent or  
10 surfactant, to assist penetration of the water into the board.

Furthermore, for all embodiments of the invention, the board material may be "turned" during treatment with the  
15 electromagnetic radiation to ensure uniform exposure.

It will be appreciated that the invention is able to provide clean recycled fibre for a number of possible uses, for example production of other board products, wood plastic  
20 components, fillers and insulating materials.

The process according to the present invention can be conducted on a mobile basis if desired.

25 The invention will be further described, by way of example only, with reference to the following non-limiting Examples and accompanying drawing (Figure 1), which illustrates the result of Example 1.



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Example 1

Two experiments were conducted as detailed under (a) and (b) below.

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(a) Samples of MDF measuring (approx. 50 x 50 x 18) mm were immersed (individually) in approximately 1000 ml of water in a non-metallic container and subjected to microwave radiation at a frequency of 2450  $\pm$  25 MHz at power levels of 3 kW to 15 kW for a period of approximately one minute. The samples were allowed to stand in the water for approximately 10 to 15 minutes. The procedure was carried out a total of three times at each power level using fresh MDF samples each time. The thickness of the samples was measured after this treatment and the results plotted in Figure 1, which is a graph of the mean of the three thicknesses of the MDF samples (after the treatment) at each power level vs. power level employed.

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(b) The procedure of (a) was repeated but using samples of MDF measuring (approx. 150 x 150 x 18) mm using power levels of approximately 12 kW and 15 kW for a period of approximately 60 seconds. The results are also plotted on Figure 1.

For the experiments of Parts (a) and (b), the water temperature was monitored and was found not to exceed 90°C.

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It can be seen from the results presented in Figure 1 that all samples swelled as a result of the combination of

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microwave treatment with simultaneous immersion in water. For the (50 x 50 x 18) mm samples, best results were obtained at power levels greater than approximately 5 kW, with the samples swelling to a thickness of 60 mm or greater. The (150 x 150 x 18) mm samples provided even greater degrees of swelling. This finding could be indicative of "greater cavity loading" at higher power levels. Although not illustrated on the graph, a further sample of (approx. 150 x 150 x 18) mm board, which was treated for about 45 seconds at 12 kW power, recorded a mean thickness swell of 92.11 mm.

All samples of the swollen material could easily be converted to a fibrous suspension in either approximately two minutes using a pulp disintegrator rated at approximately 1.5 kW or in approximately four minutes using a 700 W laboratory stirrer.

#### Example 2

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A (approx. 150 x 150 x 18) mm sample of MDF was subjected to microwave radiation at a frequency of approximately  $2450 \pm 25$  MHz at a power level of approximately 12 kW for a period of about 45 seconds and then added immediately to water at a temperature of above about 60°C and allowed to stand for approximately 10 to 15 minutes.

The MDF was found to have swollen in thickness to approximately 90.42 mm. The swollen material could easily be converted to a fibrous suspension in either approximately

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2 minutes using a pulp disintegrator rated at 1.5 kW or in approximately 4 minutes using a 700 W laboratory stirrer.

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